Fact Sheet Date: September 29th, 2009

NEW YORK STATE
FACT SHEET

Ambient Water Quality Values for Protection of Aquatic Life in Streams and Rivers

Substance(s): Phosphorus, Nitrogen and Nitrate **CAS Registry Numbers:** NA

Ambient Water Quality Value: 0.03 mg/l TP, 0.88 mg/l TN, 0.53 mg/l NO_3^-

Basis: Aquatic Life Use Impairment

Prepared By:

Alexander J. Smith
Brian T. Duffy
Lawrence E. Abele
Diana L. Heitzman

Stream Biomonitoring Unit
Bureau of Water Assessment and Management
Division of Water
NYS Department of Environmental Conservation
Albany, New York

Background

Nutrient enrichment has become a dominant source of water quality impairment throughout the United States (USEPA 2000d, Reckhow et al. 2005) with 20–40% of water quality impairment decisions arising from increased levels of nitrogen and phosphorus (Dodds and Welch 2000). The current trend of increasing eutrophication of surface waters from various human induced sources such as fertilizer application and fossil fuel combustion (Vitousek et al. 1997, Smith et al. 2003, Turner et al. 2003) has caused the United States Environmental Protection Agency (USEPA) to develop a national strategy for the development of regional nutrient criteria (USEPA 1998). This strategy is meant to facilitate the development of standards for nutrients which will prevent the common problems they cause in surface waters (e.g. low dissolved oxygen, algal blooms, increased turbidity, weed growth), inevitably resulting in the preclusion of designated uses.

Presently NYS has narrative regulations which are meant to prevent the cultural eutrophication of surface waters (Water Quality Regulations Title 6, Chapter X, Parts 700-706). The narrative standard, which applies to waters of class AA, A, B, C, D, SA, SB, SC, I, SD, and A-Special reads "none in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages." To quantify the narrative standard and to improve the protection of aquatic life in flowing surface waters of New York State the Division of Water has derived numeric guidance values for total phosphorus (0.03 mg/l), total nitrogen (0.88 mg/l), and nitrate (0.53 mg/l). These guidance are only for the protection of aquatic life use in flowing surface waters of Class AA, A, B, C, D, and A-Special waters.

The values for total phosphorus, total nitrogen, and nitrate are applied as mean base flow concentrations generated from a minimum of 3 depth integrated composite samples collected during the summer growing season. The sampling period is defined as June 1 to September 30.

The guidance values set forth here represent the results of a weight-of-evidence approach (USEPA 2000e) which enlisted multiple methods culminating in single nutrient endpoints. Several extensive statewide datasets from both wadeable and non-wadeable flowing waters were used. Guidance values were established considering the natural variation in nutrient concentrations and focused on indentifying thresholds corresponding to cultural eutrophication. The cultural eutrophication of waters in these datasets was determined based on the response of biological communities to increased nutrient concentrations and therefore directly relates the guidance to biological communities and their impairment. These relationships allow the use of biological community analyses as indicators of compliance with nutrient guidance values. Specifically, the Nutrient Biotic Index (NBI) for use with benthic macroinvertebrate communities developed by (Smith et al. 2007) can be applied in an assessment of nutrient standard compliance to compliment the numeric nutrient guidance values established in this fact sheet. It is recommended that during the collection of water chemistry samples for analysis of nutrients, benthic macroinvertebrates be sampled and analyzed using this or other metrics of trophic condition.

Derivation Methods of Guidance Values

Datasets

The derivation of guidance values for total phosphorus (0.03 mg/l), total nitrogen (0.88 mg/l), and nitrate (0.53 mg/l) was based on a weight-of-evidence approach. Multiple datasets were used in their derivation 1) NYSDEC's Rotating Integrated Basin Studies (RIBS) program statewide dataset 2) a USEPA funded statewide project to develop NYS nutrient guidance for wadeable streams and rivers (WSNC) and 3) a USEPA funded statewide project to develop NYS nutrient guidance for large non-wadeable rivers (LRNC). The analysis of these datasets used multiple lines of evidence including percentile analysis of nutrient parameters, cluster analysis, nonparametric deviance reduction and conditional probability. This fact sheet is a summary of these methods.

All three of the datasets used included data collected from across NYS. The RIBS data is considered an historical set of information since it contained benthic macroinvertebrate and water column chemistry samples collected between 1993 and 2002 from 129 locations on 116 different streams across NYS (Figure 1). Benthic macroinvertebrate samples were collected once between July and September from each location, during the same year as water chemistries. A 5-minute traveling kick sample along a 5-meter diagonal transect through a riffle area was used. In the laboratory a 100-organism subsample was removed from each sample, and each organism was identified to the lowest taxonomic level possible (usually genus or species) (Bode et al. 2002). Water chemistry samples were collected 4-10 times a year at each location using a depth-integrated wading sampler, and composited from at least three points across the stream. Water samples were analyzed by an environmental chemistry laboratory under contract to NYSDEC.

The WSNC dataset was collected during the summer sampling period (July-September) of 2008 and consisted of benthic macroinvertebrates, periphyton, and water chemistries. 100 different sites were sampled (Figure 1) within each of the four aggregate nutrient ecoregions present in NYS; "Mostly Glaciated Dairy Region" (Ecoregion 7) (USEPA 2000a), "Nutrient Poor, Largely Glaciated Upper Midwest and Northeast" (Ecoregion 8) (USEPA 2001), "Central and Eastern Forested Uplands (Ecoregion 11) (USEPA 2000b) and "Eastern Coastal Plain" (Ecoregion 14) (USEPA 2000c). Due to similarity in nutrient guidance values set by EPA ecoregions were aggregated further and treated as ecoregion 7/14 and ecoregion 8/11. Sites were selected to represent a gradient of nutrient conditions using percent forest cover as a determinant for predicting increasing nutrient concentrations. Reference sites within each ecoregion had ≥ 75% forest cover, test sites had < 75% and represented a gradient within this criterion. Macroinvertebrate communities and water chemistries were collected and processed using the methods in the RIBS dataset and described in (Bode et al. 2002). However, in this dataset water chemistries were collected once from each location. Periphyton was collected using a multi-habitat composite and a 300 cell subsample identified to genus or species (Bode et al. 2002).

Fewer samples were collected from large rivers in NYS (40) due to the limited number of river reaches classified as such. A definition of large river was developed which reads "a drainage area of ≥ 500 sq. miles, depth ≥ 1 meter and free of riffles for a distance of 20 times the wetted width at the sampling location. Benthic macroinvertebrates, periphyton and water chemistries were collected at each location. Biological communities were sampled using artificial substrate samplers (modified Hester-Dendy multiplates). Macroinvertebrates were processed using a 250 organism subsample and identification to genus or species. Periphyton was processed following the methods of the WSNC project. Details on the biological sample collection and processing can be located in (Bode et al. 2002). Water chemistries were collected and processed using the same methods described in the WSNC dataset.

Detailed information on all three datasets can be found in the aquatic life nutrient criteria publications of the NYSDEC (Smith et al. 2007, Smith and Tran 2009 and Smith et al. in progress, expected publication year 2010).

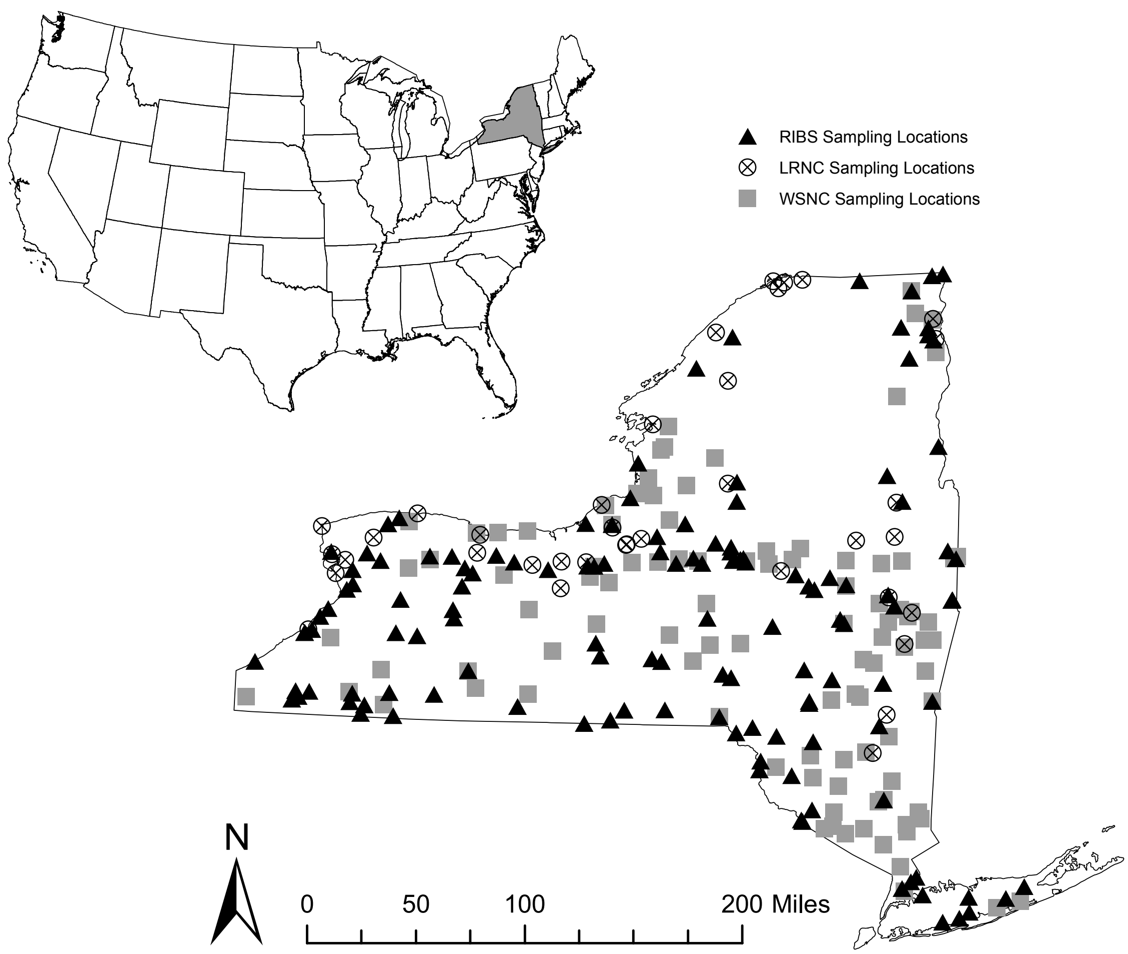

Figure 1. Map of sampling locations from all three project datasets (RIBS, WSNC, LRNC) used in the development of nutrient guidance values for the protection of aquatic life in flowing surface waters.

Statistical Analyses

All three datasets were treated separately in their analyses and brought together to define nutrient guidance endpoints. Following methods recommended by the USEPA (USEPA 2000e) a percentile analysis of the water chemistry data was performed to determine possible nutrient guidance for the primary nutrient criteria variables TP, TN, and NO_3^- (USEPA 2000e). In its technical guidance for developing numeric nutrient criteria, the USEPA suggests identifying nutrient concentrations at the 75th percentile of reference sites as criteria. It also recommends the use of the 5th-25th percentile of the entire population especially where reference sites are not established (USEPA 2000e). For the RIBS dataset which did not differentiate between reference sites and test the 25th percentile of the entire population was used. For the WSNC and LRNC datasets a modification of EPA's method was used incorporating both reference and test sites. The 75th percentile of the reference condition and the 25th percentile of the test condition were determined. The median value of the 2 percentiles for each nutrient variable was then calculated. Additionally the WSNC dataset which had further refined site classification was analyzed by ecoregion.

Results of the percentile analysis from each set of data can be found in Table 1. Combining the results into an average value for each nutrient variable (0.016 mg/l TP, 0.46 mg/l TN and 0.17 mg/l NO_3^-) (Table 1) provided a single value to be carried forward into the final weight-of-evidence nutrient guidance value. As mentioned earlier, the WSNC results were also treated by aggregate ecoregion. However, the high degree of similarity in total phosphorus and total nitrogen values between aggregate ecoregions 8/11 and 7/14 supports the discontinuation of analyzing these data by ecoregion in further analyses.

Table 1. Results from percentile analysis of nutrient data from all three datasets for Total Phosphorus, Total Nitrogen, Nitrate, Chlorophyll-a, and Turbidity. Mean results from the three datasets is also displayed. WSNC data were also analyzed separately by aggregate ecoregions 7 and 14 and 8 and 11.

Nutrient	RIBS	WSNC	LRNC	Mean	WSNC (ER 7/14)	WSNC (ER 8/11)
Total Phosphorus (mg/l)	0.016	0.013	0.02	0.016	0.014	0.012
Total Nitrogen (mg/l)	0.47	0.39	0.51	0.46	0.434	0.334
Nitrate (mg/l)	0.22	0.14	0.15	0.17	0.167	0.09

Although representative of nutrient conditions statewide, a percentile analysis lacks a connection to aquatic life use and establishment of guidance values that directly relate to designated uses. Therefore, relationships between species composition of biological communities (macroinvertebrates and periphyton), biological community metrics and nutrient concentrations were established using several different techniques. Bray-Curtis Similarity analysis (BCA) (Bray and Curtis 1957) was used to relate shifts in species composition relative to nutrient concentrations using both the RIBS and LRNC datasets. Thresholds in community metrics in response to increased nutrient concentrations were identified using non-parametric changepoint analysis (nCPA) (King and Richardson 2003, Qian et al. 2003, Qian et al. 2004, King et al. 2005, King et al. 2007). Probabilities of impairment due to nutrients were established using conditional probability analysis (Paul and McDonald 2005).

BCA was used to identify clusters of sites based on log-transformed macroinvertebrate (RIBS and LRNC datasets) and diatom species data (LRNC only) (Smith et al. 2007, Smith and Tran 2009). Resulting dendograms indicate 3 major groups of sites with species composition similarity (Figure 2) (Simon and Morris 2008) for both benthic macroinvertebrates and periphyton in the RIBS and LRNC datasets.

To determine if the clusters in the BCA were distributed along a nutrient gradient, Kruskal-Wallis one-way analysis of variance (ANOVA) was run on ranks of nutrient data. This determined whether water chemistries from sites clustered together were significantly different from other site clusters (Figure 2). If differences in nutrient concentrations were found between clusters of sites a multiple comparison test was used to test these differences for significance. In the RIBS dataset significant differences in nutrient concentrations were found between each cluster of sites suggesting greatest species similarity among sites separated by low, medium and high concentrations of nutrients (Figure 3). In the LRNC dataset significant differences were only observed between the low and high nutrient clusters of sites (Figure 3). Median nutrient concentrations from site clusters are given in Tables 2 and 3.

The BCA and ANOVA results provide better endpoints with regard to the protection of aquatic life than those of the percentile analysis. Clustering of sites with nutrient concentrations in the mid-range of the nutrient gradients suggests a continuum of trophic states from low (oligotrophic) to high (eutrophic) nutrients with sites in the middle transitioning in their biological structure and function. To avoid allowing aquatic life to transition into the eutrophic range the median values from the medium concentration clusters were averaged from both datasets for each nutrient variable. These values were used in calculating the guidance values. The resulting means were 0.036 mg/l TP, 0.75 mg/l TN and 0.36 mg/l NO_3^- . Results from each individual dataset and for benthic macroinvertebrates and periphyton are listed in Tables 2 and 3.

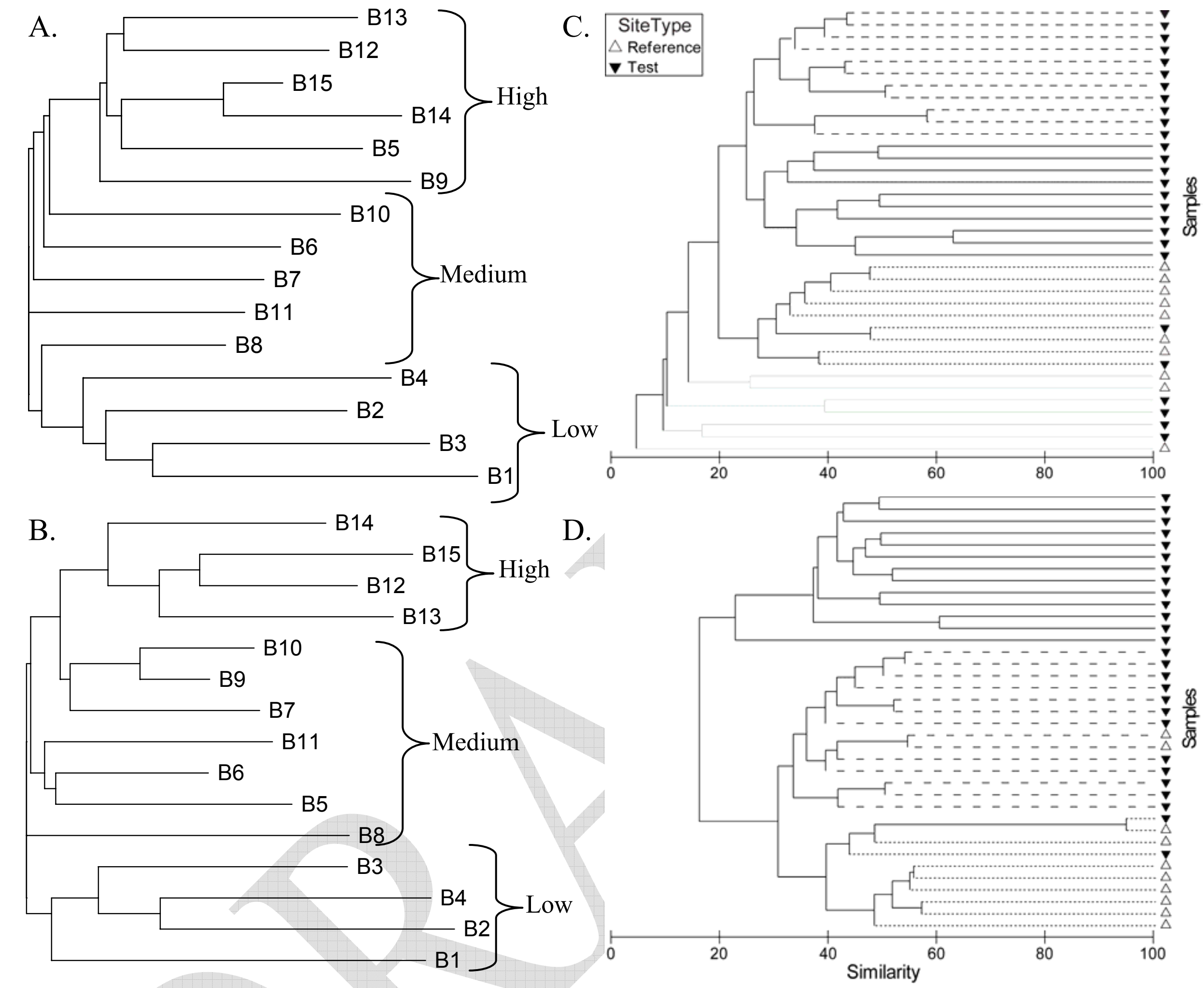

Figure 2. Bray-Curtis similarity analysis cluster diagrams: A) RIBS macroinvertebrate data and total phosphorus and B) nitrate, C) LRNC macroinvertebrate data and D) periphyton data. In all four diagrams of species data there are three clusters of sites that can be identified. Analyzing water chemistry data from these site clusters shows a gradient of nutrient concentrations.

Table 2. Median nutrient concentrations from site clusters based on benthic macroinvertebrate data identified in BCA using both the RIBS and LRNC datasets.

Nutrient	Oligotrophic		Mesotrophic		Eutrophic	
	RIBS	LRNC	RIBS	LRNC	RIBS	LRNC
Total Phosphorus (mg/l)	0.012	0.011	0.033	0.037	0.107	0.07
Total Nitrogen (mg/l)	0.34	0.45	0.81	0.68	1.82	1.06
Nitrate (mg/l)	0.13	0.15	0.45	0.31	1.44	0.36

Table 3. Median nutrient concentrations from site clusters based on periphyton data identified in BCA using only the LRNC dataset.

Nutrient	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (mg/l)	0.011	0.037	0.059
Total Nitrogen (mg/l)	0.14	0.77	0.32
Nitrate (mg/l)	0.15	0.31	0.36

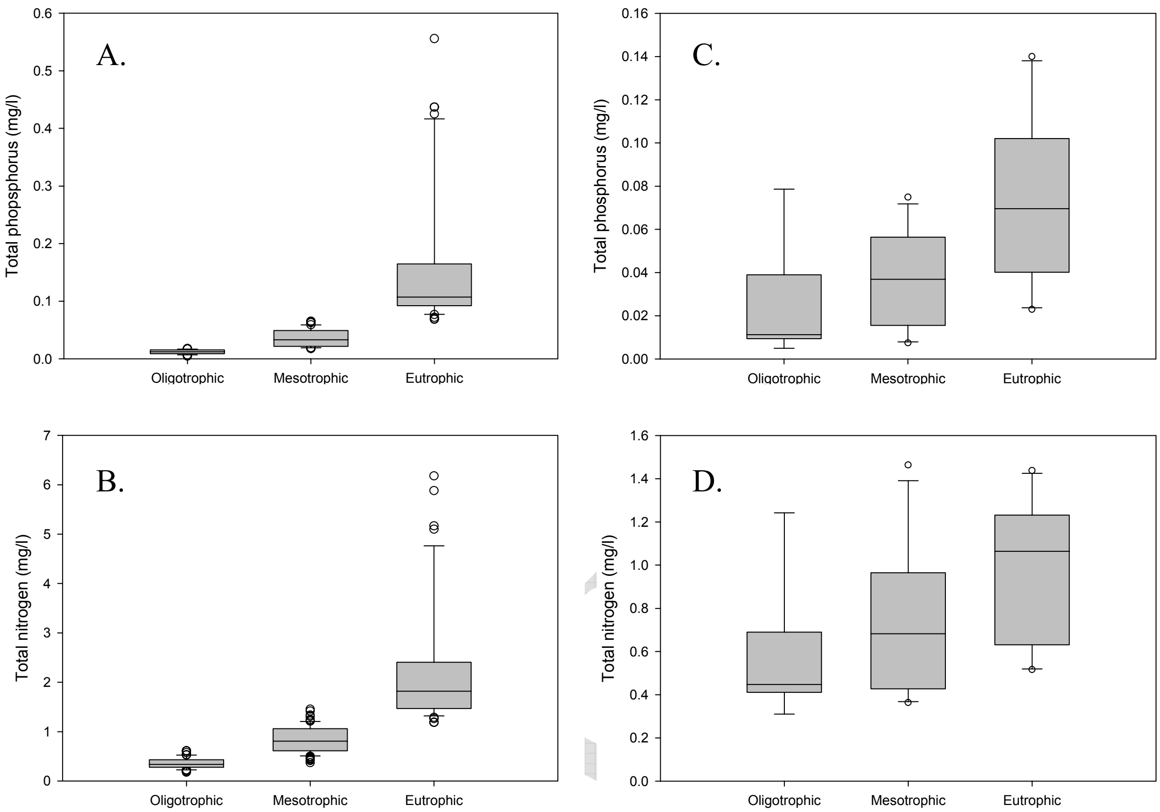

Figure 3. Total phosphorus and total nitrogen data from site clusters with low (oligotrophic), medium (mesotrophic) and high (eutrophic) nutrient concentrations from both the RIBS (A and B) and the LRNC (C and D) datasets.

To set meaningful guidance protective of aquatic life, specific values of environmental variables must be identified that cause or reflect a change in biological community structure. Nonparametric changepoint analysis (nCPA) (King and Richardson 2003, Qian et al. 2003, Qian et al. 2004, King et al. 2005, King et al. 2007) was used to identify thresholds in biological response to increasing concentrations of nutrients in both the LRNC and WSNC datasets. nCPA selects the point along the independent variable that produces the greatest amount of deviance reduction. The changepoint may be any value that creates two populations in the dataset which are separated by significant differences in their mean or variance (King and Richardson 2003, Qian et al. 2003, King et al. 2005). nCPA was run using the custom function “chngp.nonpar” (King and Richardson 2003, Qian et al. 2003) in S-PLUS 6.1 Professional (Insightful Corporation, Seattle, WA).

Biological community metrics (macroinvertebrate and periphyton) and nutrient variables shown to have significant correlative relationships in a Spearman Rank Order correlation analysis were evaluated for threshold responses using nCPA. For details on the correlation analysis see (Smith et al. 2007, Smith and Tran 2009, Smith et al. in progress, expected publication year 2010). In addition, an explanation of the biological community metrics used is provided in Appendix I. Since any one value or multiple values of the predictor variable could potentially represent a changepoint in the data there is some uncertainty in the result. nCPA estimates uncertainty in the changepoint values produced using bootstrap resampling with replacement (1000 permutations) and produces cumulative probability curves for each comparison based on the frequency distribution of changepoints. The method also allows for description of the confidence in each changepoint due to the nature of the resampling (King and Richardson 2003). Therefore, the nutrient value can be identified for certain likelihoods that a changepoint will occur. For example in this case nutrient values corresponding to the 5th, 50th, and 95th probabilities that a change point occurs are provided (Tables 4 and 5). Median values for each nutrient variable were calculated from all changepoints and the average from the two datasets was used in deriving the final nutrient guidance values. The resulting means were as follows: 0.014 mg/l TP, 0.66 mg/l TN and 0.23 mg/l NO_3^-.

Table 4. Results from nonparametric changepoint analysis (nCPA) using the LRNC dataset. Threshold responses for 5th, 50th, and 95th percentile of cumulative probabilities are given. Probability of Type I error (p) are given for the 50th only. Mean metric scores to the left and right of the 50th are provided for each water quality metric. Median values (highlighted) from all changepoints from each nutrient variable are also given.

Primary response variable	Water quality Metric	Changepoint (cumulative probabilities)			*p*	Mean metric score	
		5%	50%	95%		Left	Right
TP (mg/l)	BAP	0.028	0.131	0.143	0.0284	7.22	2.78
	NBI-P	0.011	0.011	0.036	0.0026	5.38	7.46
	NBI-N	0.011	0.011	0.152	0.0468	4.65	5.79
	HBI	0.009	0.011	0.143	0.0220	5.38	6.97
	EPT	0.008	0.03	0.131	0.0916	7	4
	DIV	0.013	0.03	0.164	0.0519	3.40	2.52
	NCO	0.008	0.008	0.131	0.0855	15	9
	Chl-a	0.075	0.131	0.143	0.0000	4.09	27.79
	% Oligotrophic	0.006	0.009	0.011	0.0029	3	1
	% Mesotrophic	0.009	0.01	0.013	0.0006	30	4
	% Eutrophic	0.011	0.011	0.077	0.0010	21	63
	PTI	0.053	0.083	0.131	0.0100	2.65	2.34
Median of all TP Changepoints		0.011	0.011	0.131			
TN (mg/l)	BAP	0.43	1.21	1.41	0.0907	7.09	5.67
	NBI-P	0.44	0.51	0.76	0.0061	5.91	7.59
	NBI-N	0.41	1.19	1.28	0.0204	5.24	6.67
	HBI	0.44	0.5	1.25	0.0285	5.69	7.07
	Chl-a	1.0	1.03	1.41	0.0051	3.23	12.58
	% Mesotrophic	0.39	0.41	0.48	0.0072	25	5
	% Eutrophic	0.44	0.5	1.14	0.0019	30	65
	PTI	1.03	1.22	1.28	0.0004	2.67	2.25
Median of all TN Changepoints		0.44	0.77	1.26			
NO_3^- (mg/l)	BAP	0.054	0.194	0.667	0.3353	7.49	6.19
	NBI-P	0.153	0.176	0.269	0.0021	5.97	7.79
	NBI-N	0.088	0.555	0.652	0.0729	5.31	6.54
	Chl-a	0.054	0.054	0.652	0.0332	19.97	5.22
	% Eutrophic	0.054	0.362	0.59	0.0533	45	68
	PTI	0.154	0.555	0.652	0.0024	2.66	2.30
Median of all NO_3^- Changepoints		0.071	0.278	0.652			

Table 5. Results from nonparametric changepoint analysis (nCPA) using the WSNC dataset. Threshold responses for 5th, 50th, and 95th percentile of cumulative probabilities are given. Probability of Type I error (p) are given for the 50th only. Mean metric scores to the left and right of the 50th are provided for each water quality metric. Median values from all changepoints from each nutrient variable are also given.

Primary Response Variable	Water Quality Metric	Change Point (cumulative probabilities)			*p*	Mean metric score	
		5%	50%	95%		Left	Right
TP	MoreTol	0.091	0.11	0.242	0.000000003	4.42	21.21
	LessTol	0.008	0.06	0.141	0.003877000	22.04	33.60
	Eutroph	0.014	0.017	0.027	0.000000004	26.88	60.95
	Swlndiv	0.008	0.016	0.043	0.000016050	2.26	2.81
	DMA	0.015	0.017	0.021	0.000000004	56	22
	SiltInd	0.015	0.017	0.099	0.000004457	15	37
	SppDtm	0.012	0.016	0.031	0.000012490	35.37	45.88
Median of all TP Changepoints		0.014	0.017	0.043			
TN	MoreTol	0.88	1.8	3.67	0.000000330	4.52	17.56
	LessTol	0.31	0.55	1.53	0.000212700	17.68	29.79
	Eutroph	0.41	0.8	0.87	0.000000239	32.70	62.65
	Swlndiv	0.26	0.51	0.56	0.000002347	2.22	2.82
	DMA	0.41	0.54	0.7	0.000000019	56.17	23.67
	SiltInd	0.54	0.55	0.79	0.000000085	12.10	37.88
	SppDtm	0.29	0.34	0.53	0.000042780	32.70	44.22
Median of all TN Changepoints		0.41	0.55	0.79			
NO_3^-	Eutroph	0.095	0.255	0.521	0.000001782	31.09	58.37
	Swlndiv	0.044	0.185	0.19	0.000006581	2.26	2.82
	DMA	0.163	0.185	0.255	0.000000017	56.22	23.63
	SiltInd	0.186	0.194	0.296	0.000000097	12.18	37.83
Median of all NO_3^- Changepoints		0.129	0.189	0.275			

The methods used thus far for deriving nutrient guidance values have utilized both the chemical and biological components of the available datasets. Incorporation of biological information in the analyses ensured the connection of guidance values to the protection of aquatic life. However, to this point analyses have focused on detecting thresholds corresponding to initial shifts in biological community structure and function as measured in the BCA and nCPA respectively. These methods, although robust in associating nutrient values to changes in aquatic communities, do not directly identify thresholds associated with biological impairment of surface waters.

In order to do relate nutrient concentrations to biological impairment Conditional Probability Analysis (CProb) was used on New York State's current set of benthic macroinvertebrate community metrics used in the assessment of water quality. Overall water quality impairment was determined for each of the sampling events in the WSNC dataset using NYS's multimetric approach based on benthic macroinvertebrate data (Bode et al. 2002, Riva-Murray et al. 2002). This method calculates species richness (Spp), Ephemeroptera–Plecoptera–Trichoptera richness (EPT) (Lenat 1988), Hilsenhoff's biotic index score (HBI) (Hilsenhoff 1987), and percent model affinity (PMA) (Novak and Bode 1992). The results of each of these indices are placed on a common 10 scale and the mean of these adjusted values is determined. The result, called the biological assessment profile (BAP) score, is a single value for which a four-tiered scale of water quality impact (non, slight, moderate, severe) has been established. New York State's water quality monitoring program has set the threshold between slight and moderate impact as the point above which remedial action for a waterbody typically occurs (Smith et al. 2007).

CProb can be used in detecting the point at which biological impairment occurs based on predetermined biocriteria given a concentration of some environmental variable, in this case nutrients. The probability of exceeding the biocriteria can be established given any value of the environmental variable (Paul and McDonald 2005). Using the biological metrics and associated impairment criteria (Bode et al. 2002) in Table 6 the WSNC dataset was evaluated against total phosphorus, total nitrogen and nitrate.

In order to maintain aquatic life in flowing waters the nutrient values carried through from the CProb analysis to the final weight-of-evidence should represent a high degree of protection. Therefore using nutrient values associated with higher probability of impairment such as 75% allows too many waters to become impaired before remedial action is taken. Using the values corresponding to 50% probability of impairment will ensure their protection. The results (Table 6) of the CProb analysis indicate impairment (BAP $\geq$ 5.0) is 50% probable at concentrations of 0.05 mg/l TP, 1.71 mg/l TN and 1.58 mg/l NO_3^-. An example of the conditional probability results is also provided in Figure 4. Only results from the BAP were used in defining the final guidance values because it is a multimetric and integrates the individual results of each metric and impairment determinations are based solely on this value.

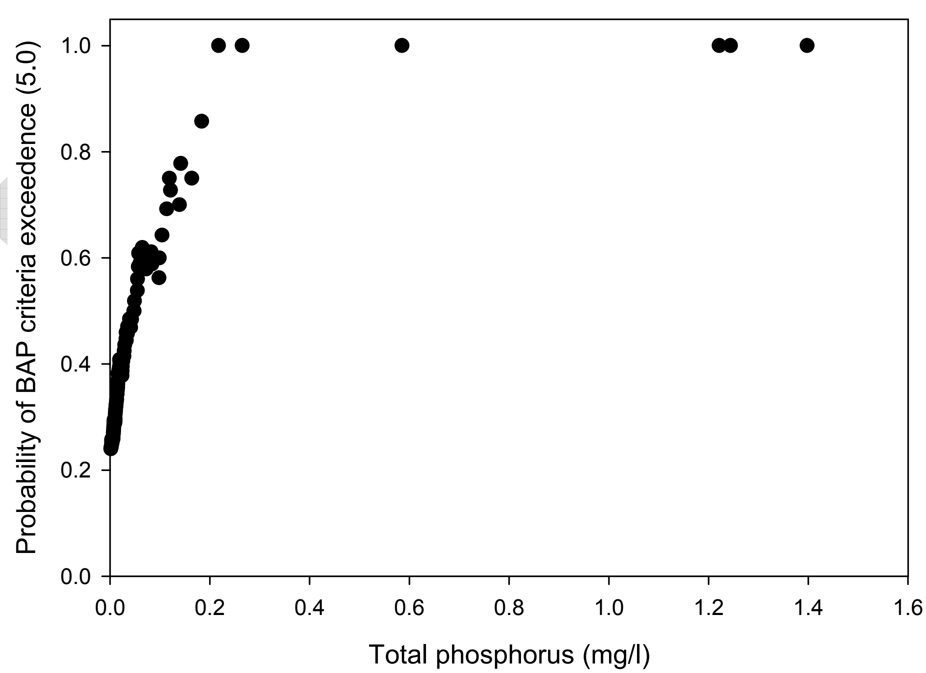

Figure 4. Conditional probability plot showing the probability of exceeding the BAP score impairment criteria of 5.0 given a gradient of total phosphorus values. Once above 2.0mg/l TP there is a 100% probability of exceeding the criteria.

Table 6. Conditional Probability Analysis (CProb) results using the WSNC dataset and applicable biological water quality assessment metrics. The evaluated biocriteria for each individual metric is provided along with nutrient values corresponding to the 25th, 50th and 75th probabilities of exceeding the criteria.

Nutrient Variable	Metric	Biocriteria	Probability of Exceeding Biocriteria		
			25th	50th	75th
TP (mg/l)	BAP	5.0	0.005	0.05	0.164
	HBI	6.5	0.585	-	-
	PMA	49.0	>0.002	0.015	0.164
	EPT	5.0	>0.002	0.016	0.057
	Spp	18.0	>0.002	0.061	0.119
TN (mg/l)	BAP	5.0	0.19	1.71	3.67
	HBI	6.5	2.05	3.67	-
	PMA	49.0	>0.08	1.13	2.05
	EPT	5.0	>0.08	0.53	1.38
	Spp	18.0	>0.08	1.9	2.87
NO_3^- (mg/l)	BAP	5.0	0.045	1.58	2.69
	HBI	6.5	2.189	-	-
	PMA	49.0	>0.014	0.643	1.662
	EPT	5.0	>0.008	0.503	1.58
	Spp	18.0	>0.014	1.662	2.696

Weight-of-Evidence

To define final guidance values for nutrients the results of each line of evidence (percentile, cluster analysis, change point and conditional probability) were combined in a weighted mean following the USEPA's recommended weight-of-evidence approach (USEPA 2000e). Weights were applied to individual results based on strength and significance of the analysis, the confidence in the data used, and best professional judgment (BPJ). Results from metrics established specifically for or directly related to nutrients in water were weighted more heavily than those associated with general pollution or in the case of the percentile analysis had no connection with the response of biota. Table 7 lists the individual metrics, their nutrient values, and weights applied in the final weighted mean to determine the nutrient guidance values for total phosphorus, total nitrogen and nitrate. The weight-of-evidence is a sound means to establishing guidance values which incorporates the variance in nutrient concentrations in the environment and their varying effects on biota.

Table 7. Nutrient concentrations used in deriving the final guidance values for total phosphorus, total nitrogen and nitrate. Values are listed from the individual statistical analyses (Percentile = Percentile analysis, BCA = Bray-Curtis Similarity Analysis, nCPA = Nonparametric Changepoint Analysis and CProb = Conditional Probability Analysis) along with the weights used (W). The weighted average of these values is also listed (Guidance Value).

Nutrient Variable	Percentile	W	BCA	W	nCPA	W	CProb	W	Guidance Value
Total phosphorus (mg/l)	0.016	1	0.036	3	0.014	4	0.05	2	0.03
Total nitrogen (mg/l)	0.46	1	0.75	3	0.66	4	1.71	2	0.88
Nitrate (mg/l)	0.17	1	0.36	3	0.23	4	1.58	2	0.53

The proposed guidance (Table 7) resulting from the weight-of-evidence approach (TP 0.03 mg/L, TN 0.88 mg/L and NO_3^- 0.53 mg/L) are similar to values identified by others to protect aquatic ecosystems from eutrophication (Figure 5). Dodds identified 0.03 mg/L TP and 0.35 mg/L TN as necessary in-stream levels to control nuisance benthic Chl-a levels (Dodds et al. 1997). While defining stream trophic states Dodds also used frequency distributions to establish TP of 0.025 mg/L and TN of 0.7 mg/L as the boundary between oligotrophic and mesotrophic conditions (Dodds et al. 1998). USEPA guidance values for the nutrient ecoregions in NYS suggests criteria of 0.033 mg/L TP and 0.54 mg/L TN (USEPA 2000d, a). All three studies present nutrient criteria that are similar to those identified in this fact sheet (Table 7 and Figure 5).

Some researchers have proposed slightly higher but similar values (Havens 2003, Sheeder and Evans 2004, Stevenson et al. 2006) (Figure 5). Stevenson (2006) compared the effects of nutrients on algal biomass in streams and found the majority of responses occurred between the ranges of 0.01-0.03 mg/L TP and 0.4-1.0 mg/L TN. The nutrient guidance values proposed in this fact sheet fall within these ranges. Sheeder and Evans (2004) identified thresholds of impairment in a Pennsylvania watershed at 0.07 mg/L TP and 2.0 mg/L TN, both higher than the guidance proposed here. Their values were based on impairment without considering shifts in biotic assemblages at much lower concentrations. If guidance values for NYS did not use the weight-of-evidence approach and relied only on impairment thresholds the guidance would be similar to the findings of Sheeder and Evans.

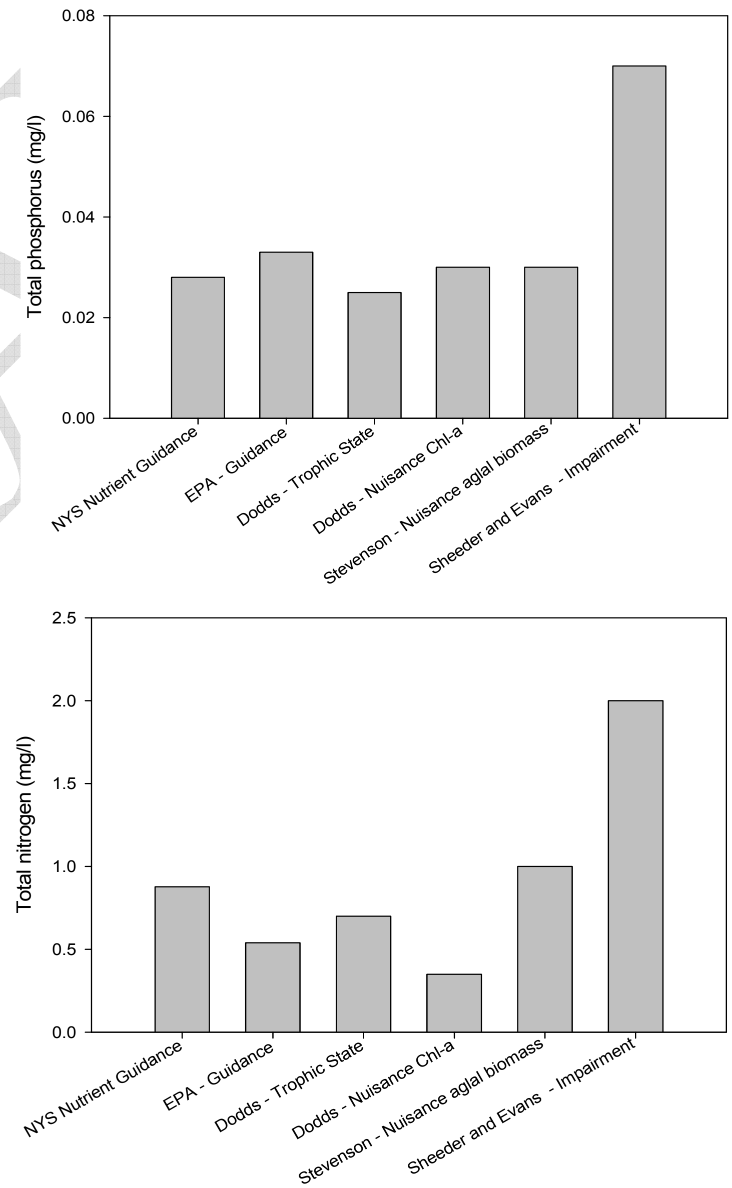

Figure 5. Comparisons of NYS guidance values for total phosphorus and total nitrogen with other published nutrient guidance values.

Establishing protective, meaningful nutrient guidance is imperative to prevent further eutrophication of surface waters. The use of a weight-of-evidence approach allows for the inclusion of different methods of establishing protective nutrient concentrations. The techniques employed here are adaptable and result in easily perceived criteria that can be readily applied in other guidance value and standards development efforts in New York State. The proposed nutrient guidance values will protect biotic communities of flowing surface waters from degradation and help maintain the current natural trophic status of many of NYS's rivers and streams. For further information on the derivation of nutrient guidance values for the protection of aquatic life in NYS please refer to (Smith et al. 2007, Smith and Tran 2009, Smith et al. in progress, expected publication year 2010).

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Appendix I. Description of Biological Community Metrics

Benthic Macroinvertebrate Community Metrics:

Species Richness (Spp):

This is the total number of species or taxa found in the sample. Higher species richness values are mostly associated with clean-water conditions.

EPT Richness (EPT):

EPT denotes the total number of species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) found in a subsample. These are considered to be mostly clean-water organisms, and their presence generally is correlated with good water quality.

Hilsenhoff's Biotic Index (HBI):

The Hilsenhoff Biotic Index is calculated by multiplying the number of individuals of each species by its assigned tolerance value (tolerance values can be found in Appendix 15.10), summing these products, and dividing by the total number of individuals. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10). Tolerance values, listed in Appendix 15.10, are mostly from Hilsenhoff (1987) however some have been recalibrated based on NYS datasets. High HBI values are indicative of organic (sewage) pollution, while low values indicate lack of sewage effects.

Percent Model Affinity (PMA):

This is a measure of similarity to a model non-impacted community based on percent abundance in 7 major groups (Novak and Bode, 1992). Percentage similarity as calculated in Washington (1984) is used to measure similarity to a kick sample community of 40% Ephemeroptera, 5% Plecoptera, 10% Trichoptera, 10% Coleoptera, 20% Chironomidae, 5% Oligochaeta, and 10% Other. For Ponar samples, the model is: 20% Oligochaeta, 15% Mollusca, 15% Crustacea, 20% Non-Chironomidae Insecta, and 20% Chironomidae, and 10% Other.

Species Diversity (DIV):

Species diversity is a value that combines species richness and community balance (evenness). Shannon-Wiener diversity values are calculated using the formula in Weber (1973). High species diversity values usually indicate diverse, well-balanced communities, while low values indicate stress or impact.

NCO Richness (NCO):

NCO denotes the total number of species of organisms other than those in the groups Chironomidae and Oligochaeta. Since Chironomidae and Oligochaeta are generally the most abundant groups in impacted communities, NCO taxa are considered to be less pollution tolerant, and their presence would be expected to be more indicative of good water quality. This measure is the Sandy Stream counterpart of EPT richness.

Nutrient Biotic Index (NBI):
The Nutrient Biotic Index (Smith et al., 2007) is a diagnostic measure of stream nutrient enrichment identified by macroinvertebrate taxa. The frequency of occurrences of taxa at varying nutrient concentrations allowed the identification of taxon-specific nutrient optima using a method of weighted averaging. The assignment of tolerance values to taxa based on their nutrient optimum provided the ability to reduce macroinvertebrate community data to a linear scale of eutrophication from oligotrophic to eutrophic. Two tolerance values were assigned to each taxon, one for total phosphorus, and one for nitrate. This provides the ability to calculate two different nutrient biotic indices, one for total phosphorus (NBI-P), and one for nitrate (NBI-N). Study of the indices indicate better performance by the NBI-P, with strong correlations to stream nutrient status assessment based on diatom information.

Periphyton Community Metrics:
Pollution Tolerance Index (MoreTol and LessTol):
Indicator of diatoms tolerant to nutrient and organic enrichment. MoreTol denotes the percentage of diatoms that are very tolerant while LessToll denotes the percentage of diatoms that are only somewhat tolerant.

Eutrophic Diatoms (Eutroph):
This is the percentage of diatoms in a sample that are eutraphentic. Higher percentages indicate higher levels of eutrophication.

Shannon-Weiner Diversity (Swlndiv):
Species diversity is a value that combines species richness and community balance (evenness). Shannon-Wiener diversity values are calculated using the formula in Weber (1973) and natural logarithms. High species diversity values usually indicate diverse, well-balanced communities, while low values indicate stress or impact.

Diatom Model Affinity (DMA):
DMA is a percent similarity, reference-based community metric which compliments the PMA for benthic macroinvertebrate communities. It was derived through analysis of generic and species composition from NYS reference condition streams. Using a model diatom community composed of a combination of 4 major groups the DMA compares the samples similarity to the model. High similarity to the model indicates minimal disturbance while low similarity suggests perturbation.

Siltation Index (SiltInd):
The percent relative abundance of diatoms in genera containing mostly motile species. Higher numbers of motile species indicate greater siltation and disturbance.

Diatom Species Richness (SppDtm):
This is the total number of species or taxa found in the sample. Higher species richness values are mostly associated with clean-water conditions.